Compound Risks of Climate Change:

Implications to Japanese economy and society

National Institute for Environmental Studies


The aim of this report is to publicize the research activities and key outcomes of the research project, “Study on socioeconomic risks to Japan caused by global climate change impacts”, funded by the Environmental Restoration and Conservation Agency（ERCA）（JPMEERF20182001）（duration period April 2018 to March 2021）, with support of the Ministry of the Environment, Japan.

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Sub-theme and theme leaders

（1）Analysis of information concerning climate change impacts outside Japan and related risks
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（2）The effect of overseas impacts of climate change on Japan’s economic activities via the international supply chain
Keisuke Nansai, National Institute for Environmental Studies（NIES）

（3）The effects of changes in food production due to climate change impacts on food imports in Japan
Gen Sakurai, National Agriculture and Food Research Organization

（4）Climate fragility risk in Asia
Kentaro Tamura, Institute for Global Environmental Strategies（IGES）

（5）Theoretical aspects of climate change and security concepts
Seiichiro Hasui, Ibaraki University

（6）Measures to address climate change risk in international systems
Yukari Takamura, University of Tokyo


Summary

The increasing frequency of heavy rainfalls and severe typhoons is said to be caused by the adverse effects of climate change. Among various climate change risks, physical damages by natural disasters in Japan are increasingly being acknowledged by the public and have been investigated in many studies. However, studies from overseas have pointed out that climate change impacts in various parts of the world can increase economic and sociopolitical risks through various routes. Climate change impacts therefore need to be recognized as a **compound risk** that includes diverse domestic and international impacts. To date, this approach has not yet been taken in Japan.

This aim of this research project is to deepen our knowledge from the perspective of each of the six types of climate risks shown in Figure. Until now, these risks have merely been discussed in Japan, even though they are particularly important for national risk management. As shown in the figure, these risks are not only components of the compound risk for Japan, but each type of risk can also contribute to the others. The research for this project is ongoing, but the findings and results obtained at this stage are as follows.

(1) Corporate activities are affected by climate change through various routes. In general, companies have a greater awareness of the effects of short-term risks such as torrential rains and floods, but they are not necessarily be aware of risks resulting from high temperatures or slow-onset events that appear gradually over time.

(2) We are developing an international trade model that represents the import and export of 5041 products. We can now reproduce past performance values, and we plan to use the model to show the relationship between past disasters and changes in quantity of trade. It is expected that an increase in the number or severity of disasters in a region will affect trade between that region and Japan.

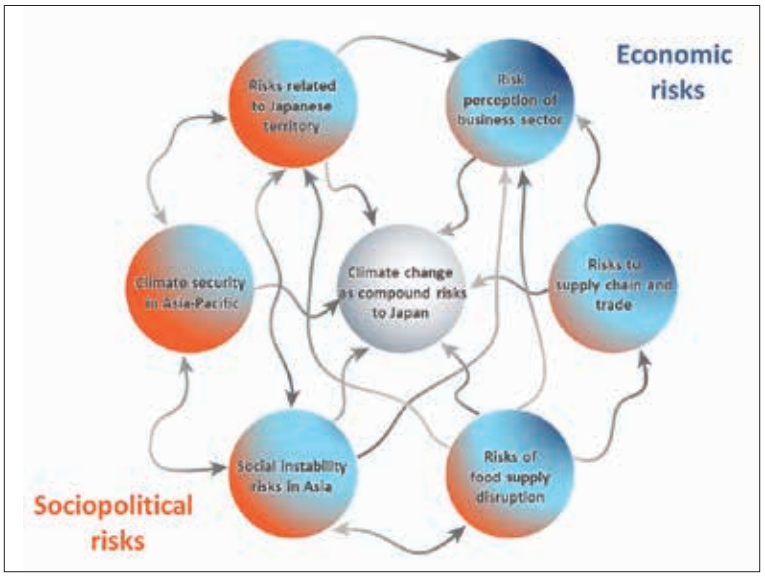
(3) Because of the effects of drought and high temperatures, it is expected that world food production will decline if no countermeasures are taken in the future. The world population is expected to continue increasing, so Japan, which imports a large amount of food, needs to consider the regions from which food (especially grain) is procured as well as its food supply methods.

(4) Targeting Asian countries that have strong ties with Japan, we independently developed a climate vulnerability index based on multiple indicators. This index can be used to show the vulnerability of countries to climate change impacts and their reliance on emergency humanitarian assistance from abroad, including from Japan.

(5) The concept of climate security is related to other types of security concepts. Although studies have clarified the strong links between food and energy security and climate security, climate mitigation actions are likely to have positive effects in other areas of security, such as maritime and human security.

(6) Island countries such as Japan are affected by sea level rise, which could lead to Japan's territory, territorial waters, and Exclusive Economic Zone shrinking in the long run. In addition, the number of refugees overseas is increasing as a result of climate change, and there is a growing demand for a response in the international community. It is important for the Japanese stakeholders to start discussing these issues.

Figure. The six climate change risks assessed in this research project



What is the compound climate risk to Japan?

—About the project—

The frequency of extreme weather events such as heavy rainfall and intense summer heat has been increasing globally in recent years, and climate change is said to be the cause. Japan has experienced severe rainfall and typhoons that have led to the loss of hundreds of lives and thousands of dwellings. However, risks associated with climate change impacts are not limited to those experienced in Japan. For example, in 2011, extreme rainfall in Thailand flooded many factories along rivers. As a result, many automobile and computer-related industries in developed countries had to stop their production lines for several months because they could not procure parts from those flooded factories. Sea level rise has displaced people living in the Pacific island nations, and migration to Australia and New Zealand is already on the rise. Agricultural products such as coffee and vanilla beans are going to grow in different areas from today's cultivation areas if global warming continues. Many studies suggest drought related to climate change will worsen food shortages and cause conflicts in Africa and the Middle East. These examples indicate that climate change impacts outside Japan could pose risks to Japan in many ways, both directly and indirectly.

The term "compound risk" is used when various risks are related to each other in a complex manner and aggravate the total level of risk. The term has been increasingly used to express risks arising from climate change. However, there has been little debate in Japan over compound risk as it applies to climate change and what it could mean for Japan's security. The aim of this research project is to deepen our understanding of six types of climate risks that have not been discussed in detail in Japan but that could have serious impacts. As mentioned previously, physical damages resulting from domestic natural disasters are, of course, one of the risks of climate change, but they are not included in this study because people are already aware of such risk, and many studies are already underway on this topic. The six risks addressed in this project are illustrated in the circles in Figure 1, where blue represents economic risk and red represents sociopolitical risk. The two colors are mixed in different ratios in each circle, with the color distribution representing the risk allocation. As the arrows in Figure 1 show, these risks are not only components of compound climate risk, but they also work as driving forces of the other risks. The six risks and related project activities are briefly summarized below.

Risk 1: Risk perception in the business sector. This research proceeds from the perspective of the kinds of climate change impacts that companies recognize as risks to themselves. Companies are expected to face different types of climate change risks according to their respective business types. What risks are common to all industries? Are there any risks that industries are not yet aware of but that could become significant in the future? In addition, because Japanese companies import resources and procure a large amount of goods from overseas, we consider the impacts from a regional perspective and where they are most likely to occur.

Risk 2: Risks to the supply chain and trade. Here, we are developing a model that uses import and export data to analyze the impact of overseas disasters on Japan's trade volume. This model could be used to explain the case in which Japanese companies suffered economic losses, for example, as a result of the flooding in Thailand in 2011. By understanding Japan's trade structure and its relation with climate-related disasters, it will be possible to predict which industries in Japan will be affected by extreme weather events overseas in the future.

Risk 3: Risks of food supply disruption. We evaluate Japanese food security, particularly in terms of supply. Japan's food self-sufficiency rate is currently less than 40% (on a calorie basis). As the frequency and severity of abnormal weather increase globally, the international prices of wheat and other staples will fluctuate. In the future, as the world population continues to grow and food demand increases, how will global fluctuations in food supply affect Japan's food imports? To answer this question, we must be able to estimate future changes in the production of major grains in each region of the world. In addition, we also need to take into account how much people will be able to respond to changing climate conditions through breed improvement, irrigation, and other adaptation measures. We plan on generating estimates of future production under various scenarios.

Risk 4: Social instability in Asia. Japan is located in Asia, and therefore, stability in Asia is important for Japan's security. Japan

Project representative

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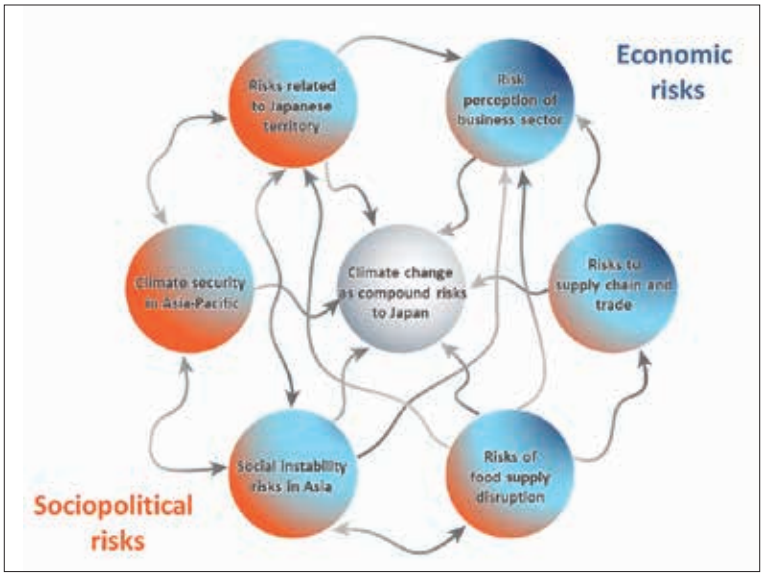
supports developing countries through its Official Development Assistance, but recent increases in extreme weather patterns have made it necessary to construct bridges and roads in these countries with more severe climate-related assumptions. Furthermore, in these countries, post-disaster social instability (e.g., riots and looting) could lead to deteriorating security, posing a greater sociopolitical risk. Therefore, we are aiming to develop an index that measures the vulnerability of Asian countries to climate change from various perspectives and to use the index as criteria for determining whether or not assistance from other countries is needed. We will also engage with experts from several countries and develop suggestions for what we can do to reduce vulnerability in developing countries.

Risk 5: Climate security in the Asia-Pacific region. Our goal in studying this risk is to extend the concept of climate security, which has been studied mostly in Europe and the United States for more than 20 years, to the Asia-Pacific region. Although "climate security" is an unfamiliar notion in Japan, studies have been and continue to be conducted on how environmental destruction/deterioration causes water and food shortages and thereby increases conflicts among neighboring people. This causal relationship indicates that efforts to protect the environment will also help to avoid human conflict. The idea that climate change will impair the materials and social stability necessary for humans to live in dignity is also part of the concept of "climate security", but in Japan, this is generally included as part of the concept of "human security". We reorganize these concepts and ideas, and apply them to Japan and the Asia-Pacific region.

Risk 6: Risks related to Japanese territory. For this risk, we examine the impact of climate change on conventional national security. First, displacement of people has been on the agenda at United Nations Framework Convention on Climate Change (UNFCCC) meetings in recent years. As more people migrate from areas that become uninhabitable due to natural disasters and rising sea levels, a system to support these people is urgently required. This issue has begun to be discussed at the UN Office of the High Commissioner for Refugees and the UN Security Council, and collaboration between international organizations will be required to find solutions. From another perspective, Japan's Exclusive Economic Zone is predicted to shrink as a result of sea level rise, which poses another national security risk. Although these issues have not been addressed in Japan, it may be pressured to respond to these and similar issues in the near future.

In the next sections, we explain our research progress on these risks and the related six sub-themes to date. Based on these achievements, we expect that discussions of these important issues will be advanced in Japan to prepare to meet the challenges posed by climate change risk.

Figure 1. The six climate change risks assessed in this research project



Note: The arrows indicate relationships between risks. Blue represents economic risk and red represents sociopolitical risk. The color distribution represents the risk allocation for each risk.

Risk perception in the business sector

Sub-theme 1: Analysis of information concerning climate change impacts outside Japan and related risks

Background

Climate change affects individuals and organizations in various ways, and companies are no exception. At the request of the G20 Finance Ministers and Central Bank Governors Meeting, the Financial Stability Board established the Task Force on Climate-related Financial Disclosure (TCFD) in 2015 to help the financial sector address climate-related issues. In order for investors to make decisions on investments in companies, the TCFD requires companies to disclose climate-related information in addition to conventional financial information. Climate-related risks can be broadly divided into two types: "transition risks" are those risks caused by greenhouse gas (GHG) emission reduction (mitigation) policies, and "physical risks" are those that are caused by climate change impacts, such as extreme weather. In questionnaire surveys administered to companies by the World Economic Forum every year, the greatest number of companies have responded that the biggest risk to corporate management has been the climate in recent years, indicating that corporate executives perceive that their activities and climate change are closely related.

In this way, companies are in an era where investors are required to judge and prepare for climate-related risks to themselves. However, it is difficult to accurately determine what impact climate change will have and the extent of those impacts.

Table 1. Types of climate risks to private companies

	Impact inside country	Impact outside country
Transition risks	Impact of domestic mitigation policies such as a carbon tax.	Impact of mitigation policies outside country, including criticism against use of coal power plants
Physical risks	Impact in country such as extreme rainfall	Impact outside country that indirectly affect activities inside country such as by trade

Table 2. Risks to Japanese companies arising from physical risks

Type of risk	Possible risks to Japanese companies
Short-term increase in rainfall that could result in floods	✓ Floods, typhoons, etc., causing damage to buildings and facilities ✓ Shut-down of transportation systems and logistics ✓ Workers not able to come to work due to damages in transportation system ✓ Delay in delivery of products due to supply chain shut down ✓ Extension of construction period for buildings and infrastructure ✓ Damages to agricultural products
Long-term sea level rise and high tide	✓ Loss of land and facilities near sea shore ✓ Damages to facilities near shore due to short-term high tide ✓ Delay in ship transportation due to inability to use ports
Water shortage	✓ Decrease in water use in factories, leading to decrease in production ✓ Decrease in crop yield due to water shortage ✓ Forest fire due to extraordinarily dry climate
Heat stress	✓ Decrease in labor force productivity due to heatstroke ✓ Increase in use of electricity for air conditioning during summer ✓ Loss of productivity in agricultural sector; shift of suitable climate for agricultural products ✓ Delay in delivery of products due to melting of road asphalt ✓ Shift in fishery areas due to warmer sea water ✓ Change in final consumers' preferences (can also be opportunities)
Others, including investment and reputation risks	✓ Increase in costs due to increase of risks of new investments ✓ Increase in insurance fees ✓ Price increases caused by speculation in addition to price increases caused by the above-mentioned risks

Project members

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Research outline

To understand the perception of Japanese companies regarding climate-related risks, we conducted a series of interview surveys. Climate change risks to companies can generally be divided into four types, as shown in Table 1, but the target of this project is the risk caused by climate change impacts outside Japan, so the lower right frame in Table 1 is the specific target. The risks faced by companies were comprehensively extracted from academic journals and reports on physical climate impacts, and they are summarized in Table 2. We asked representatives of Japanese companies about their perceptions of the risks described in this table. Our aim was to have as much diversity in industry type as possible in the survey group, and 11 companies agreed to participate.

Regarding inundation caused by short-term increases in precipitation, we found that most of the companies had experienced some economic losses during the 2011 flooding in Thailand. Specific damages reported included damages to buildings caused by flooding, breakdowns in electrical systems, property damage to products and materials stored in the buildings, product delivery delays because of disruption of the transportation network, costs incurred by paying wages to employees who could not commute for several months, support for other companies that suffered damage, additional labor costs allocated to confirm damage, and production delays resulting from the late arrival of some parts in the manufacturing process in Japan. The interviewees reported being better prepared for any similar future problems.

There were no reported cases where drought itself caused damage. However, there were several cases where the interviewees expressed concern. In particular, companies operating in South America, India, Thailand, Singapore, Australia, and Turkey or who imported goods from these areas expressed concern about drought. There was one case where a local worker who operated a factory in Latin America proposed that the company install a rainwater tank, under the assumption that there could be a risk of a water shortage at some point in the future.

Heat stress generally appeared to be of less concern to the interviewees as compared to other types of climate-related impacts. They did not mention, for instance, the possibility of increased use of electricity for air conditioning of rooms where products are stored or employees work. Additional wages also might be needed for workers who work outdoors because they may need more time to rest in a hotter climate. In the case of companies that operated overseas, some respondents pointed out that companies that are not sufficiently prepared for the effects of climate change are perceived as having higher management risks and to face reputation risks. Japanese companies also were paying attention to reputation risk in their overseas operations, but they did not consider Japanese consumers to be sufficiently aware of the issue to incur reputation risks in Japan.

Future plans

We found that the 11 surveyed Japanese companies were highly aware of some climate risks and preparing or considering how to deal with them. On the other hand, there were also cases in which companies had not considered how to prepare for changes that occur gradually rather than abruptly, such as rising sea levels and rising average temperatures.

Out next step is to increase sample size of companies to better capture general trends. We are starting to utilize data of questionnaire surveys conducted annually by CDP, a London-based organization. By increasing the number of companies in the sample, we will be able to clarify the characteristics of each industry type. For example, it will be possible to determine whether there are differences in risk perception between the manufacturing industry, which imports goods from overseas, and the finance and insurance industries. Also, given the different industrial and trade structures in the various countries, we should be able to identify differences in awareness between Japan and other countries.

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Risks to the supply chain and trade

Sub-theme 2: The effect of overseas impacts of climate change on Japan's economic activities via the international supply chain

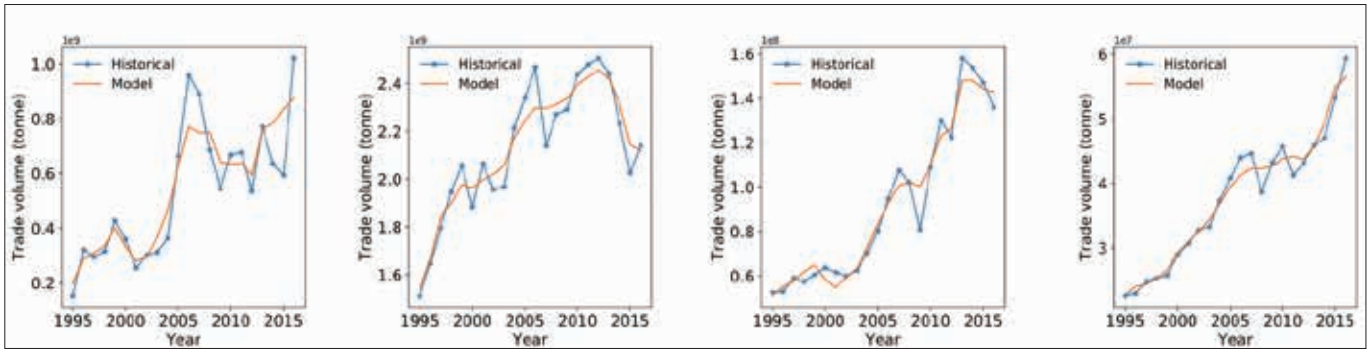
Background

The total value of Japan's imports in 2019 was about 78.6 trillion yen. It has more than doubled from 33.9 trillion yen in 1990, and the dependence of the Japanese economy on imported resources, materials, and products continues to grow. Against this background, "footprint" studies have focused on the relationship between Japanese production and consumption and the international supply chain. They have also examined global sustainability issues and Japan's consumer responsibility. This line of thinking has also led to the study of Japan's carbon footprint, which indicates the amount of greenhouse gases and fine particles ($PM_{2.5}$) that are indirectly emitted in each country throughout the world through the international supply chain as a result of Japan's final consumption. Footprint studies also have revealed the amount of land modifications caused by metal mining stimulated by demand from Japan. The overseas impact of the Japanese economy is remarkable worldwide, and it has been suggested that raising awareness of consumer responsibility is essential for global sustainability.

There are also cases where the footprint concept has been applied to quantify the involvement of the Japanese economy in social risks abroad. For precious metals, the risk undertaken by mining countries was defined by taking into account factors such as uneven distribution of resources and political instability in the mining countries, as well as the direct and indirect risk that Japan's final demand is implicitly exposed to through the supply chain. The results showed that mining risk was concentrated in capital formation and export demand. The current COVID- 19 pandemic has also been observed to have had a cascading effect on the global economy because of production constraints in each country. These facts highlight the need to establish an economic structure that is robust against risks and to identify the risks related to production activities in countries around the world as well as Japan's involvement in the supply chain.

The increase of natural disasters resulting from climate change is a production constraint of increasing concern. The previously discussed damage to production facilities caused by the 2011 flood in Thailand is an excellent example of this type of production constraint for the Japanese manufacturing industry. A worldwide increase in the frequency of natural disasters, such as floods and droughts, will increase the vulnerability of the international supply chain on which Japan's production and consumption depend, and will pose a significant risk to the Japanese economy. However, few studies have evaluated the impact of changes in the frequency of natural disasters on the international supply chain, and no study has focused on Japan, which hinders the study of Japan's ability to assess and avoid economic risk associated with climate change.

Figure 2. Example of verification of reproducibility of actual values of total trade amount by product in an international trade model (from left to right: natural gas and liquefied natural gas, crude oil, aluminum, and copper)



Project members

Keisuke Nansai, Kenichi Nakajima (National Institute for Environmental Studies (NIES))
Ryoko Morioka (National Agriculture and Food Research Organization (NARO)) fiscal year 2018 only

Research outline

The purpose of this study is to estimate changes in the international trade structure that accompany changes in the frequency of natural disasters, and analyze the effects on Japan's production and consumption system. To do so, we first modeled international trade using machine-learning methodologies. We defined international trade as a three-dimensional structure of [exporter] × [importer] × [trade commodities], and we developed a method to decompose this structure into a vector showing trade volume and a trade structure matrix showing probability of import and export. For the international trade data, we used BACI (International Trade Database at the Product-Level), which is an improved international trade database issued by the UN Statistics Bureau. In this study, we compiled international trade data for each year from 1995 to 2017, with 216 exporting countries, 216 importing countries, and 5041 products. The unit of trade volume is based on weight (tonne).

The decomposition of international trade data was performed as follows. First, we focused on each matrix defined on the three sides of the cubic data. The three aspects were (A) a table consisting of exporters and importers that showed the amount of imports and exports between countries by item, (B) a matrix of [exporters] × [items] that shows the total export amount by item of each country, and (C) a matrix of [importing countries] × [items] that shows the total import quantity by item of each country. Aspect (A) defined 5041 matrices, and (B) and (C) defined one matrix each. Next, we decomposed each of the above matrices into a vector corresponding to the trade volume (a vector with the row sum as an element and a vector with the column sum as an element) and a double probability matrix corresponding to the trade probability of the matrix element. A vector (function form) was constructed by learning the elements of the vector obtained by the above decomposition (total trade amount of each item, total import amount of each country, and total export amount of each country) and the trade probability by ridge regression. In addition to socioeconomic indicators, greenhouse gas emissions were included as explanatory variables, with the intention of taking into consideration of climate mitigation policies. Future greenhouse gas emissions and socioeconomic index values were assigned to the obtained function form, future vector elements and trade probabilities were predicted, and each result was recombined to build the future three-dimensional international trade data. We confirmed the reproducibility of model output by comparing it with actual historical values (Figure 2).

To connect international trade with Japan's production and consumption system, the 2015 version of Japan's input-output table and the corresponding international trade code for the 5041 products were used to make a direct and indirect classification by sector of Japan's final demand. We constructed a database that can identify relationships with various international trade products. In addition, we also began to develop a regional input-output table to analyze the relationship between Japan's regional demand and trade (see references below).

Future plans

In the future, we plan to add the frequency of natural disasters to the explanatory variables of the model of international trade by type of disaster and by country, incorporate the impact of natural disasters into the estimation of the international trade structure, and identify trade structures that are vulnerable to natural disasters. The frequency of occurrence of disaster types by country is available from EM-DAT (an international disaster database). Specifically, we will add these frequencies to the explanatory variables of the international trade model for floods, storms, droughts, wildfires, and extreme temperatures. In the current model, we referred to the Shared Socioeconomic Pathways of the Intergovernmental Panel on Climate Change (IPCC) for future greenhouse gas emissions and socioeconomic indicators by country. However, because there is no database containing the future values of disaster frequency, we will identify scenarios that significantly affect the trade structure by setting a large number of scenarios for increasing the frequency. In addition, we will analyze how closely related the affected trade structure is to Japan's final demand using the previously constructed database.

We are also considering adding yield data of 10 major crops to the explanatory variables to improve the model for agricultural products. This would involve the use of historical data from the World Food Organization and future yield estimates obtained in Sub-Theme 3. Through this analysis, we will examine the risks to Japan's food supply resulting from changes in the future trade structure of agricultural products in the face of changes in crop yields and disasters caused by climate change.

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What impact will climate change have on Japan's food security?

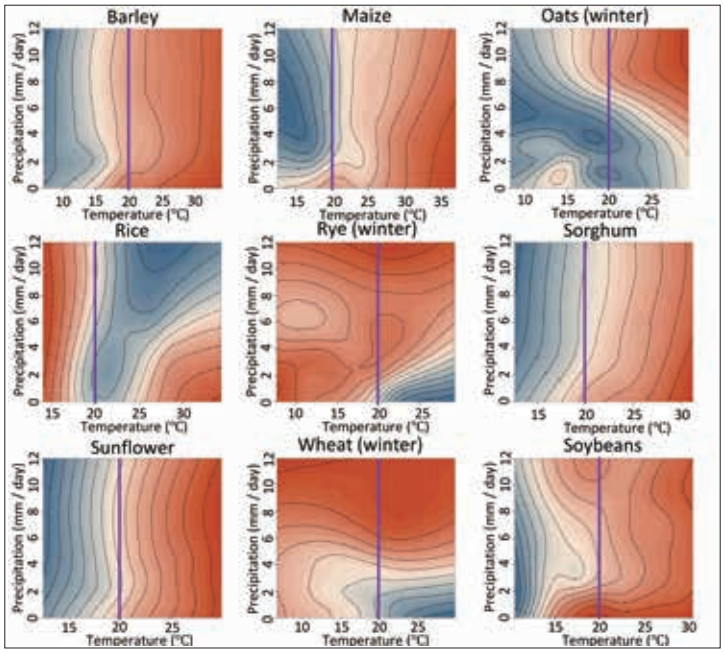
Sub-theme 3: The effects of changes in food production due to climate change impacts on food imports in Japan

Background

The world's population continues to grow, making forecasting future crop productivity an important issue. It has been suggested that crop production should be about double the current level to meet the predicted population growth through 2050. Japan produces most of its rice domestically, but it imports more than 70% of its grains and about 50% of its meat and fish. Therefore, Japan may have difficulty supplying food if severe weather patterns significantly decrease food production outside Japan. Future global crop productivity will be directly linked to food security in Japan. Many studies have analyzed the impact of climate change on crop productivity in various countries, and numerous studies have shown that future crop yields will decrease globally. When considering future food security in Japan, it is necessary not only to analyze changes in crop yields in Japan but also to predict changes in crop yields throughout the world.

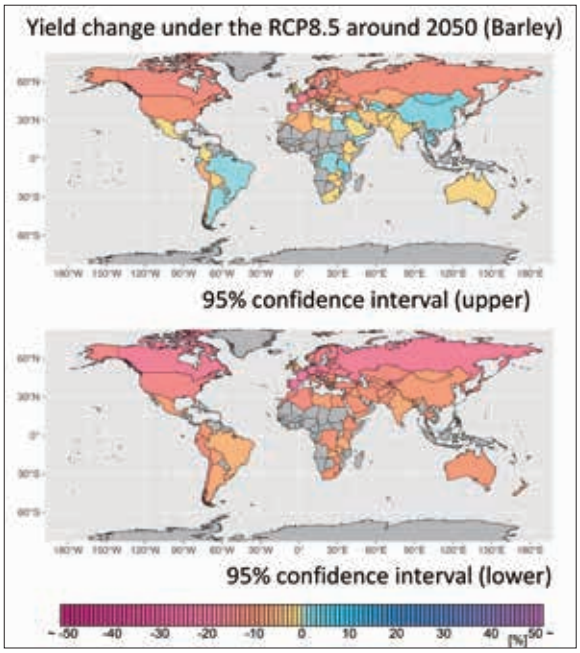
There are two important points to consider in the above-mentioned crop research from the viewpoint of food security. One is that many of the studies use process-based models (mathematical models that consider the physiological processes of crop growth), and uncertainty in predictions is not taken into account. The other is that most of the studies are limited to major crops, and other types of crop are not covered. Given the wide variety of crops that Japan imports, we need to estimate the effect of climate change on a wider variety of crops. In addition, from a policy-making perspective, we need to include evaluations of uncertainty in our predictions of potential crop yields.

Figure 3. Effect of temperature and precipitation on crop yields



The horizontal axis shows the annual average temperature (°C) during the growing period, and the vertical axis shows the precipitation (mm/day). For oats, rapeseed, rye, and wheat, the values are averaged 2 months before the harvest date. Red indicates a decrease in yield, and blue indicates an increase. The purple lines indicate 20 °C.

Figure 4. Crop yield change rate (%)



The upper and lower panels show the upper and lower values of the 95% confidence interval. The crop yield change rate (%) relative to 2010s for each country is estimated using multiple GCM outputs.

Project members

Gen Sakurai, Ryoko Morioka (fiscal year 2019-2020) (National Agriculture and Food Research Organization (NARO))

Research outline

In this study, we analyzed the relationship between crop yield and climate change for multiple crops that are important as staple foods, feeds, and edible oils (barley, cassava, corn, oats, wheat, rice, sorghum, soybean, sugar beet, sunflower, sweet potato, yam, and rye). To investigate the effects of climate on crop productivity on a global scale, we used past meteorological data and crop yield data for statistical modeling. Past meteorological data were obtained from the Climatic Research Unit (CRU), and FAOSTAT data from 1980 to 2015 were used as crop data. Whereas the resolution of CRU data is 0.5 degrees, that of the FAOSTAT data is the country level. Therefore, CRU data were aligned with cultivation area data, cultivation calendar data, and altitude data, and the average temperature and average precipitation during the cultivation periods were calculated for each country. Using these data, we analyzed the relationship between climate factors and crop yields using the generalized additive model developed.

As a result of the statistical analyses, we could obtain impact evaluation functions for potential crop yields with respect to the average temperature and precipitation during the cultivation period for various crops. The results for several crops are shown in Figure 3. Despite the complex interactions with precipitation, elevated temperatures had a negative impact on yield for most crops. On the basis of the obtained impact evaluation functions, we estimated future crop yield under the multiple climate scenarios (Representative Concentration Pathways: RCP2.6, RCP4.5, RCP6.0, and RCP8.5) using five Global Climate Models (GCMs) (GFDL-ESM2M, HadGEM2-ES, IPSL-CM5A-LR, MIROC-ESM-CHEM, and NorESM1-M). The result for barley under the RCP8.5 scenario (the high emission scenario) is shown in Figure 4 (for yield change around 2050). Even at the upper end of the 95% confidence interval, results indicate a high probability of yield loss throughout the world. Table 3 shows the global average (weighted by harvested area) yield change under RCP8.5 around 2050. Significant yield losses were predicted for barley, sorghum and corn. Because a positive effect of increased carbon dioxide on C4 plants cannot not be expected, the decrease in the yield of maize is of particular concern.

Future plans

This study also predicts future crop yields using a process-based model. During the final year of the project, we will compare results from the generalized additive model and the process-based model. In collaboration with Sub-Theme 2, we will also analyze how changes in crop productivity under future climate scenarios will affect Japan's food security along with changes in trade. In addition, we will conduct a survey on what adaptation measures can be adopted in each country and comprehensively analyze the impact of climate change on Japan's food security.

Table 3. Global average of crop yield change rate (%) around 2050 under RCP8.5 (average of five GCMs)

Crop	Average yield change (%, relative to year 2016)	95% confidence interval (upper)	95% confidence interval (lower)
Barley	-10.83	- 7.73	-13.83
Maize	- 4.97	- 1.86	- 7.97
Oats (Winter)	- 0.60	2.59	- 3.69
Rice	- 1.77	0.59	- 4.07
Rye (Winter)	0.33	3.69	- 2.92
Sorghum	- 6.98	- 3.04	-10.76
Soybeans	- 4.96	- 1.86	- 7.94
Sugar beets	- 5.68	- 2.82	- 8.44
Sunflower	- 6.77	- 2.64	-10.72
Winter wheat	- 1.14	1.93	- 4.12

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External emergency needs for extreme events in Asia

Sub-theme 4: Climate fragility risk in Asia

Background

Climate change can exacerbate extreme climatic events, such as floods, typhoons, and droughts. The socioeconomic impacts of these events can be debilitating for all countries, irrespective of their developmental status. Some of the impacts will be largely unmanageable if countries lack relevant experience and expertise, necessitating significant external emergency assistance. Approaches used in external emergency assistance are improving constantly based on the experience gained in major disasters. Countries are improving their capacity to be self-reliant in disaster relief and response, but it is apparent that there is still a need for improving coordination mechanisms, especially in the face of potentially devastating extreme events in the future. Important questions need to be answered, such as when to call for external assistance, when to respond to such calls, and how the assistance can be delivered.

Research outline

This research examines the external factors in terms of extreme climatic events that affect the well-being of countries with which Japan has strong bi-lateral relations and the climate security implications for Japan. The study evaluates the possibility of applying the critical threshold concept, which suggests that countries that receive external emergency assistance tend to have a critical threshold in terms of the scale of emergency events and the capacities at which they tend to seek external emergency assistance. If such critical thresholds exist, then it is possible for countries such as Japan that reach out with emergency assistance to design their external assistance in such a way that the support being offered can maximize the climate security of both the recipient and donor countries.

To measure the relative climate fragility of countries, we developed the Climate Fragility Risk Index (CFRI), which consists of the indicators shown in Table 4. The fragility of a country refers to a situation in which a government fails to provide a nation with security. Climate change is seen as multiplier of threats that worsen fragility. Countries with a high CFRI tend to be exposed to the physical impacts of climate change, as well as lack the ability to provide their own effective relief assistance. Therefore, they will become more reliant on international emergency assistance. Figure 5 shows CFRI values for countries in Asia and Oceania. The countries clearly differ in the extent of climate-fragility risk. The average CFRI for developing countries in Asia was 0.76, whereas it was 0.66 for the developed countries. The differences among the countries were largely a result of variations in exposure to sea level rise (Vietnam and Thailand are highly vulnerable) and volatility in food prices (Pakistan scored the highest). Among the developed countries, Australia had a relatively high CFRI because of its high exposure to water stress and high levels of food price volatility.

Future plans

The CFRI framework could be used to identify underlying factors of climate fragility risks, such as competition for resources, extreme weather events, migration, food price volatility, and the unintended effects of policies. Our goal is to determine the relationship between a country's state of climate fragility and its dependence on external assistance. We also plan to demonstrate the possibility of developing the critical threshold concept by using available data from India and Indonesia. Furthermore, we plan on conducting a survey of experts using the Delphi method to elicit important measures to strengthen external emergency assistance and maximize the climate security of recipient and donor countries.

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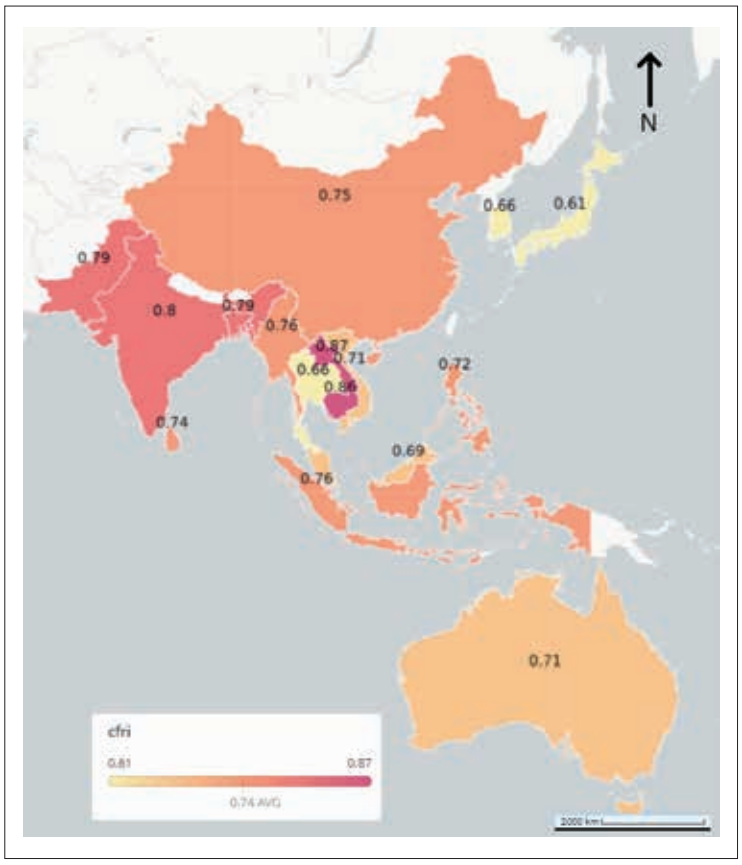
Table 4. List of indicators used in developing the Climate-Fragility Risk Index (CFRI) (Prabhakar & Shaw, 2019)

Indicator	Proxy indicator	Rationale and limitations
Local competition for water	Baseline water stress	The higher the water stress the higher the competition around water. However, water stress may not always lead to tensions and conflict depending on the local governance and social systems which are represented by the governance indicator of the World Bank. (WRI, 2018)
Extreme weather events	Climate risk index	Climate risk index is the most comprehensive risk index covering climatic hazards and has been regularly produced for most countries. (Germanwatch, 2017)
Migration and internal displacement	% of population affected by migration and internal displacement	The data provided by the Internal Displacement Monitoring Centre (2018) gives a clear picture of the number of internally displaced and migrants. These numbers were converted into % of population.
Food price volatility		Food price volatility was calculated as a standard deviation of principal food crop prices in the past decade in local currency (FAO, 2018).
Sea level rise (SLR)	% of population affected by SLR	% of population affected by SLR reflects social and economic impacts better than the mere change in SLR. (Climate Central, 2015)
Unintended effects of policies	World Bank Regulatory Quality indicator	There are no verifiable measures for unintended effects of policies yet; however, the World Bank Regulatory Quality indicator provides a close assessment for policy effectiveness, assuming that least unintended effects of policies are expected with higher regulatory quality (World Bank, 2018).
Insured losses	Insurance claims	The insured losses shows the propensity of businesses to face losses due to various risks, including the disasters. However, losses from political and social unrests may not be well represented depending on the insurance product.

Figure 5. Climate fragility of selected countries in Asia and Oceania (Prabhakar & Shaw, 2019)



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Climate change as a security issue

Sub-theme 5: Theoretical aspects of climate change and security concepts

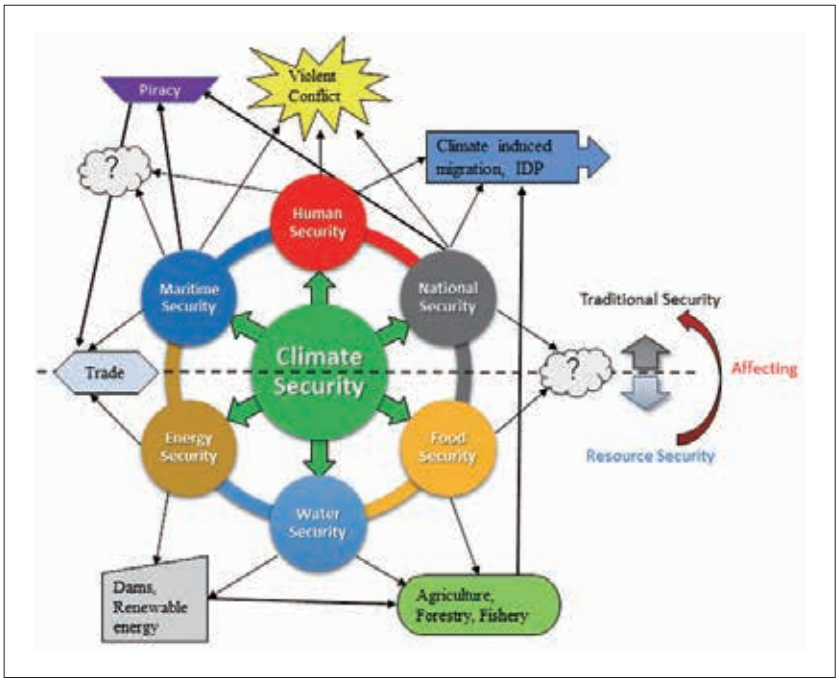
Background

In Europe and the United States, the impacts caused by climate change have been discussed in the framework of a security threat rather than only in the conventional sense as environmental issues. Over the course of the past decade or more, the concept of "climate security" has developed from these discussions. The concept remains a relatively new research topic and policy agenda item.

The concept of climate security has three stages. (1) Extreme weather resulting from climate change causes negative impacts including floods, droughts, severe typhoons, and land erosion due to sea level rise. (2) Negative impacts on fragile ecosystems lead to loss of crops, reduced yields from fishing, and economic downturns. These in turn cause water and food shortages and the forced displacement of people (i.e., environmental refugees). (3) As a result, societies become more destabilized, political conditions deteriorate, and in the worst case, they escalate into armed conflict. In contemporary international society, developed countries and international organizations have no choice but to become indirectly engaged in regional conflicts even if they are far from the home country or region. Experts have pointed out that a country's military itself must have a system and equipment to be able to respond to extreme weather.

Thus, climate change is recognized as a "threat multiplier" that amplifies existing threats, and it directly or indirectly poses a security threat to countries throughout the world. Therefore, the climate security concept is becoming established as a way to address climate change in terms of security. However, research in this area is lacking in Japan, which has offered little leadership on this topic in the global scientific community. Over the past several decades, Japan has not successfully integrated its security policy with larger international security concerns. However, if climate change is a threat to security, Japan should be able to contribute to the world's security policies, particularly in the fields of technology and economics related to climate change. For these reasons, the study of climate security both as a concept and policy making is very important.

Figure 6. Structure of climate security



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Research outline

The purpose of the research in this sub-theme is to discover how the impacts and risks associated with various climate-related economic and social changes will affect Japan's "security in a broad sense" through analyzing scientific and political discourse throughout the world.

Current discussion on Japan's climate security can be divided into domestic factors and foreign factors. In terms of domestic economic and social changes, discussions have mainly focused on human security and economic losses, including those related to climate disasters, public health, and adverse effects on agriculture, forestry, fisheries, and tourism. Foreign concerns include political instability caused by a country's inability to respond adequately to the adverse effects of climate change, which could hinder the activities of Japanese companies. Other important topics are displacement of people, changes in shipping routes in the Arctic Ocean, changes in fishing grounds, and energy issues.

By surveying scientific and political research on climate security in Europe and the United States, we have found that the concept of climate security can be positioned as an argument that links and integrates various security fields, including traditional security and resource security, as shown in Figure 6. The links between the various security areas vary in strength. For example, based on the number of scientific papers and their content, the concepts of food security and energy security appear to have stronger linkages than some of the other security fields.

Furthermore, it is clear that resource security affects traditional security. Even though they are not directly connected in Figure 6, it is important to account for maritime security when considering food security, particularly shipping routes. Also, maritime security and energy security are important elements of the national security of Japan, a country with very limited natural resources. Water security is also extremely important when addressing issues related to human security. In this way, climate security is linked to all of the various security issues, which is why it is located as the origin or central connection point in Figure 6.

The final goals of this research are to (1) collect knowledge about the impact of climate change on Japan's security and (2) present a unified theory of "climate security" policy that aims to reduce the risks related to climate change by considering not only the Japan-US alliance, which is the foundation of Japan's security, but also the relationships between the other developed and developing countries.

Future plans

In the future, we plan to propose localized "climate security" policy options for Japan after analyzing and integrating the knowledge gained from scientific research papers and policy documents from the international community.

We have found that the appropriate response to climate change requires the cooperation of military and non-military organizations. Military organizations generally have the equipment and supplies necessary for relevant response activities and can operate in harsh conditions and environments such as those encountered in disaster-stricken areas. In Japan, disaster relief provided by the Self-Defense Forces has been identified as the most expected role of the nation (Cabinet Office, 2018, "Opinion Poll on JSDF and Defense Issues").

Because the effects of climate change are borderless, security measures against these effects will lead to the formation of a new international order. An example of a major climate security risk in East Asia is super typhoons, even if any particular typhoon does not hit the Japanese islands. If Japan can take a leading role in regional disasters such as typhoons, it will build trust with neighboring countries. Therefore, organizations or institutions that can oversee and respond to security risks resulting from climate change in East Asia are essential. In addition, it is important to improve governing capacity to realize adaptive policies that reduce climate disasters, and for that purpose, it is necessary to build and maintain linkages between domestic policies and foreign assistance.

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Risks related to Japanese territory

Sub-theme 6: Measures to address climate change risk in international systems

Background

As the impacts of climate change become more serious around the world, various international institutions are beginning to deal with climate change risks. The UNFCCC and the Paris Agreement are aimed at addressing losses and damages resulting from climate change in developing countries, especially those that can be partially mitigated by reducing GHG emissions as well as by implementing various adaptation measures. Furthermore, other international institutions that are less directly relevant to climate change have started to act against climate change by integrating climate change risks into their organizational objectives. In recent years, the UN Security Council has also come to call for climate change risk analysis and strategic management to address conflicts. Climate change risk is now considered to lead to social instability, as well as threaten international peace and security. Similarly, climate change and its associated risks can affect Japan's security as well.

Research outline

The UNFCCC stipulates the general obligations of developed countries to support developing countries on the assumption that each Party deals with climate change risks on its own. In 2013, the Warsaw International Mechanism for Loss and Damage was established to address climate change risk in developing countries as part of promoting adaptation measures (policies to prepare for climate change impacts). This mechanism has three missions: to gain an understanding of comprehensive risk management and strengthen knowledge; to support dialogue with related organizations, enhance collaboration, and promote synergies; and to support actions, such as funding, technology, and capacity development.

The Paris Agreement sets out global goals for adaptation (Article 7.1) to promote adaptive capacity, strengthen resilience, and reduce vulnerability to climate change, while encouraging the Parties to implement adaptation planning processes and actions. It also sets out the obligations of the Parties to cooperate in strengthening adaptive action (Articles 7.7, 7.9). In addition, the Warsaw International Mechanism is placed under the Conference of the Parties, serving as the meeting of the Parties to the Paris Agreement (CMA) (Article 8.2). In the work plan (2017–2021) agreed upon at the 22nd Conference of the Parties (COP22) in 2016, five strategic pillars were set: (i) slow onset events, (ii) non-economic losses, (iii) comprehensive risk management approach, (iv) displacement of people, and (v) actions and support. An expert group was established for (i)–(iv), and a Fiji Clearinghouse for risk transfer, such as insurance, was established under (iii).

The strategic pillars (i), (ii), and (iv) prioritize actions to protect people from climate change risks, and (iii) prioritizes risk countermeasures. However, to date, no specific measures have been taken except for (iv), although the Fiji Clearinghouse (iii) has seen sporadic information exchange, and initiatives outside the climate regime are making tangible progress. For example, the InsuResilience Global Partnership for Climate and Disaster Risk Finance and Insurance Solutions, which consist of governments, international organizations, civil society, and private companies, was set up after the G20 in 2017 to address climate change risk.

Displacement of people (iv), which is the most studied field among the five pillars, is generally carried out in collaboration with intergovernmental organizations such as the UN High Commissioner for Refugees, International Organization for Migration, and International Labor Organization, as well as non-governmental organizations. The goal is to achieve a coordinated and integrated approach with respect to the displacement of people and other international human rights protection obligations.

In addition to the aforementioned displacement of people, other measures to respond to climate change risks are being promoted by international institutions outside the official climate regime. The UN Human Rights Council, as part of its 2015 Human Rights Council Resolution 29/15 (Human Rights and Climate Change), conducted a detailed study on the impacts of climate change. Human Rights Council Resolution 35/20 (Human Rights and Climate Change) requested that the UN High

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Commissioner for Human Rights prepare a report (A/HRC/38/21) on the effects of slow onset events and the protection of human rights of transnational immigrants. Impacts of climate change are likely to negatively impact human rights in some areas. Climate change measures should therefore be in line with internationally established human rights protection obligations.

In addition, since 2017, the UN Security Council acknowledged in its resolution that adverse impacts of climate change, such as droughts and food shortages have contributed to the occurrence of conflicts in Africa. As noted in previous sub-themes, climate change risks threaten international peace and security; furthermore, they act as "multipliers" that amplify the frequency, intensity, and length of conflict.

Turning to Japan's security, sea level rise has become a problem that affects the survival of the Pacific island nations, and Japan is not an exception. A rising sea level could lead to the loss of some of Japan's Exclusive Economic Zone and further complicate territorial and fishery issues with neighboring countries (Figure 7). For this and other reasons, it is necessary to conduct climate change impact assessments while paying attention to the climate change risks that are of great importance to Japan from the perspective of economic benefits and security.

Future plans

We need to further investigate how various international institutions, including both climate and non-climate-related institutions, can integrate climate change risks into their respective activities and aim for effective minimization of risks. We will proceed with research to examine the structure of desired governance. We aim to clarify the risks that are internationally important and determine appropriate responses through international collaboration. We also will clarify priority issues and measures to be taken as part of Japan's diplomatic activities.

Figure 7. Japan's Exclusive Economic Zone (EEZ). Small islands are important elements in the determination of the size of the EEZ.

(Source: Japan Coast Guard Website, https://www1.kaiho.mlit.go.jp/JODC/ryokai/ryokai_setsuzoku.html)

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Conclusion: Preparing for the Compound Risk of Climate Change

Based on the results of the research conducted on the six risks that compose the compound risk of climate change, the risks that Japan faces become clearer. The question then arises: How should we prepare for these risks?

First, Japanese companies must sustain their business activities while facing various climate-related risks. The risks vary depending on the type of business and the countries with which a company trades. Related risks include not only material risks such as supply chains, but also non-material risks such as corporate reputation. It is necessary to consider what kind of climate change risks each company is exposed to and prepare for those risks in many ways. The Japanese economy depends on imports of goods from abroad. In the future, it is expected that frequency of abnormal weather events will increase overseas, so it is necessary to reconsider Japan's procurement processes. For example, it may be better to build a system that allows rare metals to be reused domestically rather than to rely on imports.

The same can be said for food, in the sense that Japan relies heavily on food imports. This research project focuses only on basic grains such as wheat and soybeans, but other crops such as coffee, cacao beans, and vanilla beans will also be affected by climate change. In addition, the temperature of seawater could affect marine ecosystems and fisheries in the future. As with other imported goods, Japan needs to consider its future sources of food.

Floods and typhoons are a popular topic in Japan, but natural disasters that occur overseas receive much less attention. Many countries are suffering from natural disasters that are as severe as or even worse than Japan's every year. In developing countries, these disasters may cause not only physical damage but also social unrest. Japan provides humanitarian and development assistance to countries in the Asian region in particular, but to continue to provide effective assistance, Japan must pay attention to a wide range of climate change risks, including sociopolitical risks.

In many studies, mostly published by European and American scholars, the compound risks of climate change are dealt with under the concept of "climate security". The Security Council has addressed climate change as it affects people (climate refugees) who can no longer live in places where they used to live because of abnormal weather and rising sea levels. In addition, conflicts have arisen because of increased competition for food and water due to droughts. Until now, such problems have seemed to be unrelated to Japan, but Japan may become involved in the near future, and it needs to start taking part in the climate security discussion.

Japan is a country surrounded by the sea. Sea level rise, changes in marine ecosystems, and melting sea ice in the Arctic all will have various effects on Japan's national security. It is necessary to consider these kinds of climate change risks, including factors affecting Japan's relationships with neighboring countries.

The most efficient way to minimize climate risk itself is to reduce GHG emissions (i.e., impose mitigation measures). Today's average global temperature is already 1 °C higher than the average temperature in the pre-industrial period, causing heat waves and other extreme weather regionally. The Paris Agreement aims to keep the average global temperature increase at less than 2 °C and within 1.5 °C if possible. To reach that goal, we would have to have net-zero global GHG emissions by 2050.

The world has changed dramatically in the spring of 2020 because of COVID-19. GHG emissions declined temporarily as people's mobility around the world was restricted and production activities declined. However, emissions will increase once the world economy recovers. In Europe and the United States, notions such as "green recovery" or "build back better" are being proposed, which would concentrate investments in rehabilitating the coronavirus depressed economy to sectors that are effective in reducing emissions, such as renewable energy and information technology. A system that comprehensively manages all risks, including climate change risks and various other risks, is required around the world.

Compound Risks of Climate Change:
Implications to Japanese economy and society

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